

## Wind Tunnel Averages

**Background:** When engineers perform wind tunnel tests to measure the forces of drag and lift on a model, they use a unit of measurement called a “newton”. Newtons are named after the famous English physicist, Sir Isaac Newton. A newton is the unit of force it takes to change the velocity of a mass of 1 kilogram, by 1 meter/second over 1 second. Think of a 1 kilogram section of a wing, flying at 250 meters per second. A force of 1 newton would change the velocity of the wing section from 250 meters per second to 251 meters per second, in one second.

If, for instance, a researcher wishes to test the lift experienced by a section of a wing, he or she will embed sensors in various parts of the wing. Each sensor will measure the force of lift on a specific area of the wing. After those values are fed into a computer, the computer will display them in newtons. The researcher can then average all of the values and find the average lift over the entire wing. This same approach can be used for drag.

**Directions:** An average is a way to approximate a value for a large set of numbers. For example, to find the approximate length of the steps you take when you walk, we could measure three, four or ten of your usual walking steps. Then we could average them to find out how long a stride you usually take.

To find an average, follow these two steps:

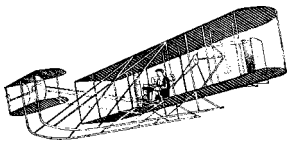
**Step 1:** Add all of the numbers together.

**Step 2:** Divide the sum by the number of numbers.

The result of this division is the average of the numbers.

For example, let’s say an engineer embedded three sensors in a wind tunnel model to measure the lift force. The computer reported the following values from each sensor:

250 newtons  
300 newtons  
350 newtons

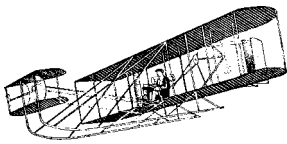


Say that the engineer wanted to find the average of the lift forces over the entire wing. He/She would perform the following steps:

**Step 1:** 250 newtons + 300 newtons + 350 newtons = 900 newtons

**Step 2:**  $\frac{900 \text{ newtons}}{3} = 300 \text{ newtons}$

The average lift force over the entire wing was 300 newtons.



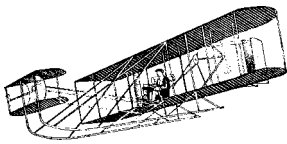
## Exercise

**Directions:** A researcher wanted to find out the quantity of the lift force experienced by different wing types during a wind tunnel test. She embedded three sensors in each of three types of wings: delta, straight, and tapered straight. Her results can be found in the table below. Your task is to find the average lift force for each of the three wing types. Put your answers in the appropriate squares in the table.

### Lift Tests

Wing / Sensor #	1	2	3	Sum	Average
delta	600 newtons	611 newtons	610 newtons		
straight	328 newtons	350 newtons	270 newtons		
tapered straight	390 newtons	433 newtons	440 newtons		

She performed the same experiment again, except that she measured the drag force from the sensors. Her results can be found in the table below. Find the average drag force for each of the three wing types. Put your answers in the appropriate squares in the table.



### Drag Tests

Wing / Sensor #	1	2	3	Sum	Average
delta	26 newtons	32 newtons	23 newtons		
straight	65 newtons	55 newtons	60 newtons		
tapered straight	40 newtons	44 newtons	39 newtons		

**Question 1:** Which wing shows the greatest amount of average lift?

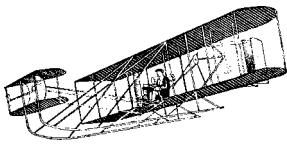
**Question 2:** Which wing shows the least amount of average lift?

**Question 3:** Which wing shows the highest individual lift sensor reading?

**Question 4:** Which wing shows the greatest amount of average drag?

**Question 5:** Which wing shows the lowest individual drag sensor reading?

**Question 6:** If you were to build an airplane, which wing would you use? Why?



## Wind Tunnel Averages

### Exercise 1 Key

#### Lift Tests

Wing / Sensor #	1	2	3	Sum	Average
delta	600 newtons	611 newtons	610 newtons	1821 newtons	607 newtons
straight	328 newtons	350 newtons	270 newtons	948 newtons	316 newtons
tapered straight	390 newtons	433 newtons	440 newtons	1263 newtons	421 newtons

#### Drag Tests

Wing / Sensor #	1	2	3	Sum	Average
delta	26 newtons	32 newtons	23 newtons	81 newtons	27 newtons
straight	65 newtons	55 newtons	60 newtons	180 newtons	60 newtons
tapered straight	40 newtons	44 newtons	39 newtons	123 newtons	41 newtons

**Question 1:** *delta: 607 newtons*

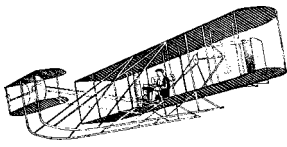
**Question 2:** *straight: 316 newtons*

**Question 3:** *delta: sensor #2 = 611 newtons*

**Question 4:** *straight: 60 newtons*

**Question 5:** *delta: sensor #3 = 23 newtons*

**Question 6:** *The delta because it has the highest lift and the lowest drag. Other answers may be appropriate if the reasoning is good.*



## Graphing Results

**Preparation:** The lesson Wind Tunnel Averages should be completed prior to starting this lesson.

**Background:** When using the four Tools of Aeronautics, engineers create many billions of numbers, which altogether are called data. Wind tunnel tests, flight simulations, Computational Fluid Dynamics and flight tests all produce huge amounts of data. It is very difficult for a human to sift through and analyze millions and millions of numbers. Larger and larger computers have been built to help engineers perform their analysis tasks. One of the fastest modern computers can perform a billion mathematical operations in one second. It would take a human 406 days (without a break!) to do the same task. However, even though the computer can process the massive volumes of data generated by the Tools of Aeronautics, a human engineer is still needed to make decisions based on the data. Computers can display information in many different ways. One of the most effective methods of displaying numerical data is on a graph. Using graphs, engineers can very rapidly analyze and make decisions based upon very large amounts of data.

**Directions:** In this lesson, students will learn how to create a bar graph based on the averages calculated in the lesson Wind Tunnel Averages.

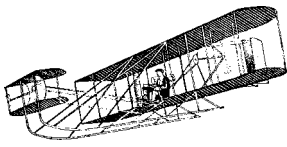
A bar graph has three basic parts:

### **Title**

All bar graphs need a title that tells what kind of data is being shown.

### **Label for Horizontal Axis**

The horizontal axis needs to have a label that identifies the type of data being displayed on that axis (for example, test flights of the X-99).



### **Label for Vertical Axis**

The vertical axis needs to have a label that identifies the units of measurement being used (for example, the maximum altitude reached during a test flight)

### **Scale for Vertical Axis**

The vertical axis needs to have a scale that lists the units of the measurement used (for example, one mark equals 5,000 feet)

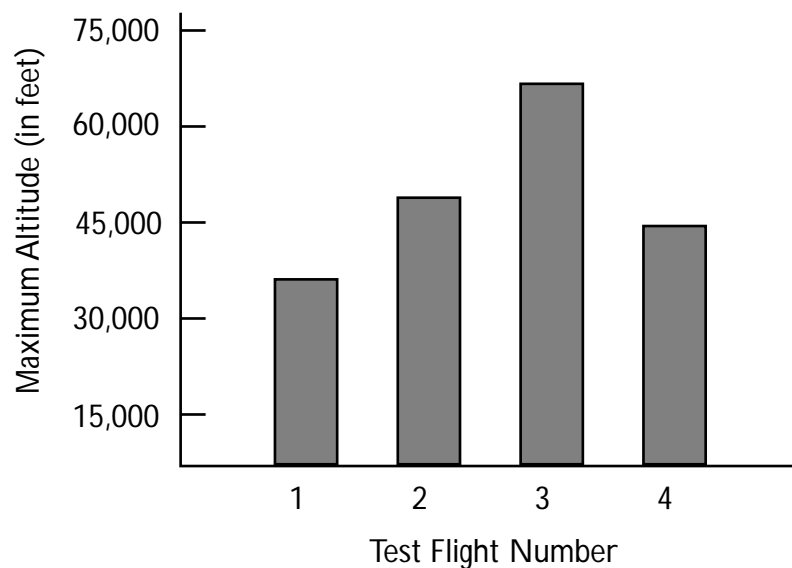
The following information has been used for the graph below.

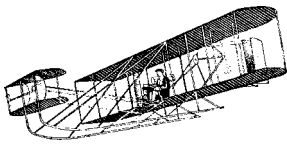
*Title - "X-99 Flight Test Results"*

*Label for Horizontal Axis - "Test Flight Number"*

*Label for Vertical Axis - "Maximum Altitude"*

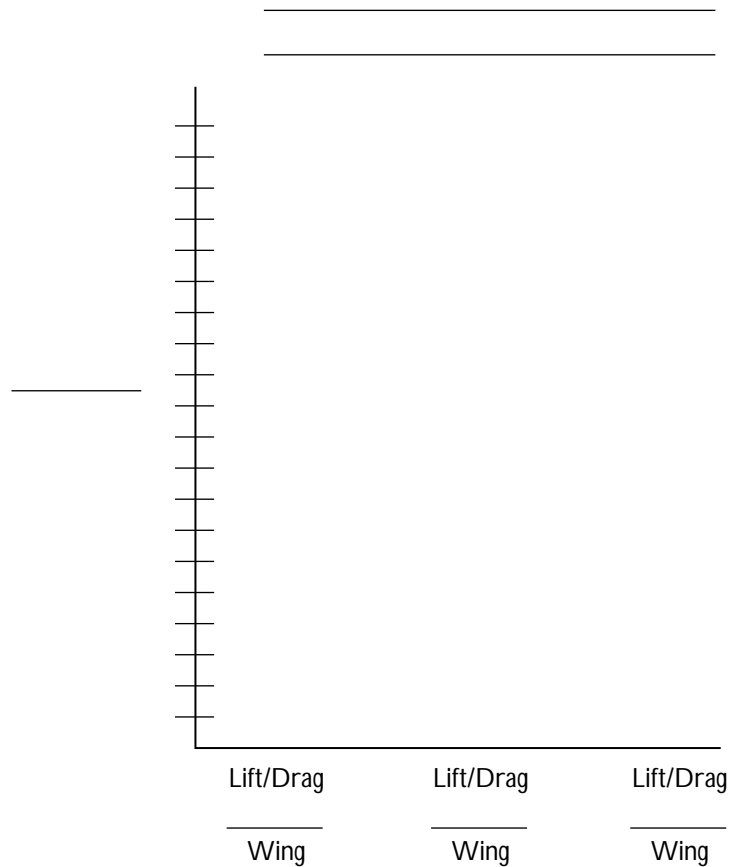
**Example bar graph**  
***X-99 Flight Test Results***



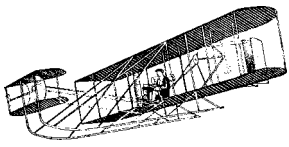


## Exercise 1

**Directions:** Create a bar graph from the averages calculated in the lesson *Wind Tunnel Averages*. Use the template below to create your bar graph. The bar graph should display the average lift and drag for each wing type. Unlike the example bar graph, you will draw two bars for every wing type — one for lift and one for drag.







## Exercise 1 – Key Wind Tunnel Test Results

